CODES AND STANDARDS ENHANCEMENT INITIATIVE

2005 Title 24 Building Energy Efficiency Standards Update

CODE CHANGE PROPOSAL FOR:

Hourly Water Heating Calculations

DRAFT MAY 15, 2002

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Overview

Water heating energy is regulated by the California building energy efficiency standards along with energy for space conditioning (heating and cooling). The energy budget is the sum of water heating and space conditioning energy, so that tradeoffs can be made between the two energy components [§151(b)]. Energy use in the standard design and the proposed building is currently reported in source Btu per square foot per year. There is no consideration of when the energy is used. As time dependent valuation (TDV) is used for assessing building energy performance, it is necessary to calculate water heating energy for each hour, like heating and cooling loads. This proposed code change introduces a calculation procedure for estimating hourly water heating energy.

Description

This proposed code change will modify the calculation procedure for estimating water heating energy so that it produces results on an hourly basis, which is consistent with TDV. The change requires that a custom budget approach be used to develop the water heating budget. Movement to a custom budget approach is directly related to TDV, as the current method of determining the water heating budget (Equation 1-N in §151(b)) produces only an annual budget, which is incompatible with TDV. The custom budget procedure is similar to the procedure currently used for residential space conditioning and involves the following:

- The basecase water heating system will be separately defined in §151 of the standard for systems serving individual dwelling units and for systems serving multiple dwelling units. The standard design for systems serving individual dwellings is a storage type gas water heater with a standard distribution system. The standard design for systems serving multiple dwelling units is a central system with recirculation and controls to turn off the pump when it is not needed. Defining the standard design separately for systems serving multiple units addresses a loophole in the standards[1].

- The ACM approval manual will specify the modeling assumptions to be used for calculating water heating use for both the proposed design and the standard design, including the hourly schedules, inlet temperatures, and other modeling assumptions. The recommended modeling assumptions are consistent with the current assumptions, but address the needs of hourly calculations and TDV.

- The ACM approval manual specifies the hourly calculation method to be used in calculating TDV energy for both the proposed and standard design water heating system. The proposed hourly calculation method is not new but is a simple modification of the current methodology.

- The calculation method includes a modified procedure for accounting for distribution system losses multipliers, which is proposed in a separate code change proposal[2].

This code change proposal applies to all residential occupancies, including single family homes, low-rise multifamily buildings and high-rise multi-family buildings. However, the definition of the standard design is proposed to be different for water heating systems serving individual dwelling units and multiple dwelling units.

While most water heaters in California are gas and TDV is less of an issue for gas consumption, the tradeoff procedure for water heating must permit electric or propane water heaters, and for these water heater types, TDV is quite significant. Even though most water heaters are gas, the need for tradeoffs requires this code change.

[1] See Code Change Proposal for Multifamily Water Heating, PG&E/HMG, Draft April 26, 2002.

[2] See the chapter on "Hot Water Distribution Systems" in Part I, Measure Analysis and Life Cycle Cost, Eley Associates, April 11, 2002.

Benefits

There are a number of benefits associated with this code change proposal and the related code change proposals on distribution systems and multifamily systems. These are summarized below:

- Simplicity. Assuming the need to move to an hourly water heating method because of TDV, the proposed custom budget approach is simpler to develop than the current method of determining the water heating budget (see §151(b) and Equation 1-N). While this equation works for annual energy calculations, it could only work with TDV if there were a separate equation or set of equation coefficients for each climate zone, each fuel type (propane or gas) and for each defined standard design (central system vs. individual). The complexity of developing such equations is daunting.

- Consistency. More consistency is gained when the energy budget and energy for the proposed design are calculated with the same methods, assumptions and techniques. This is inherently the case with a custom budget approach, while more difficult with the current approach. Modeling rules can also be updated more easily.

- Accuracy. The proposed method is more accurate, especially with regard to distribution systems (see related code change proposal). More accuracy saves energy by assuring that tradeoffs are made fairly and result in equal or better energy savings.

- Closes Loopholes. The custom budget recommendation closes a significant loophole in the standards where multifamily buildings with central water heaters get an unjustified credit because the standard design is defined as individual water heaters for each dwelling unit.

- Peak Loads. The proposed hourly method is needed to assess the impact of measures on peak demand for electricity.

- TDV. The proposed calculations work with the proposal for time dependent valuation of energy.

Environmental Impact

There is no environmental impact associated with this proposed code change.

Type of Change

There are several components of this proposed change. Using the new hourly water heating calculation procedures and adopting the revised procedures for distribution systems are modeling changes. The shift to a custom budget approach for water heating is also a modeling change, necessary in order to simplify implementation of TDV. The related proposal to change the definition of the standard design for the systems serving multiple dwelling units changes the stringency of the standard for such systems and is a modification to the prescriptive requirements.

Technology Measures

This proposed code change does not require any water heating equipment, systems or technologies that are not already well established in the marketplace.

Performance Verification

There are no new performance verification needs related to this code change, since the change is not expected to significantly affect the types of water heating systems or equipment currently being installed.

Cost Effectiveness

The modeling changes (hourly calculations and custom budget approach) do not require life cycle cost analysis since they do not affect the underlying stringency of the standard. Neither the mandatory measures nor the prescriptive requirements are affected by these changes. The cost effectiveness of the PG&E/HMG proposal to change the definition of the standard design for systems serving multiple dwelling units is addressed in a separate document.

Analysis Tools

The recommended modeling changes will require that MICROPAS and EnergyPro be updated. The algorithms and assumptions for the revisions are specified in this document and would be implemented in the residential and nonresidential[3] ACM manuals.

Relationship to Other Measures

This code change proposal is coordinated with three other code change proposals:

- Time Dependent Valuation (TDV) – Economics Methodology, PG&E and HMG, March 14, 2002. This document was presented at the April 2, 2002 public workshop at the CEC.

- Code Change Proposal for Multifamily Water Heating, Draft April 26, 2002, PG&E and HMG. This work identifies loopholes related to multi-family water heating and proposes that central systems with recirculation be considered the basis of multifamily water heating systems.

- Part I, Measure Analysis and Life Cycle Cost (chapter on Water Heating Distribution Systems), Eley Associates, April 11, 2002. This work by Davis Energy Group proposes modifications to the water heating distribution system multipliers and the basecase water heating distribution system for single family homes. Note that some of the recommendations in this report supersede the original work.

Acknowledgments

This work is completed by Eley Associates under contract to PG&E. Charles Eley was the project manager. Tianzhen Hong and Alexandra Pligavko assisted in the development of the hourly calculation procedure. Significant contributions were made by Dave Springer and Marc Hochelle at Davis Energy Group, Nehemiah Stone at HMG, and members of the CEC standards team, including Bill Pennington, Bryan Alcorn, Rob Hudler, and Elaine Hebert.

Methodology

The approach is to use the existing equation for load dependent energy factor, but to adapt it for use with hourly calculations. The average daily consumption, hourly schedules of hot water use, and temperature rise are back calculated to maintain consistency.

Results

The goal of this proposed code change is to develop an hourly calculation method that:

[3] The nonresidential ACM has calculation procedures for high-rise residential buildings which are affected by this proposal.

- Works with TDV energy and produces hourly results.
- Is consistent with the current modeling assumptions.
- Accommodates the proposed definitions of the standard design water heating systems for systems serving individual dwelling units and systems serving multiple dwelling units.
- Implements the revised distribution loss procedures.

In pursuing these goals, several tasks are performed, including:

- Modifying the LDEF calculation methods to work on an hourly basis.
- Modifying the calculation procedures to result in an hourly adjusted recovery load (HARL). This requires that we implement the recommended distribution system credits developed under another standards research project. This involves agreeing to an hourly schedule of hot water use that is consistent with the current modeling assumptions and defining other inputs such as the temperature rise between the inlet and supply.
- Defining the standard design water heating systems, which are the basis of the water heating energy budgets using the proposed custom budget approach. Most of this work on multi-family water heating systems is documented in a separate research report.[4]

Modifying the Load Dependent Energy Factor Method

A key aspect of the existing water heating methodology is the load dependent energy factor (LDEF). The LDEF was developed by Davis Energy Group in the early 1990s to deal with the impact of load on the efficiency of a water heater. The idea is that with low loads (i.e., hot water demand), the standby component is a larger fraction of energy use and this will drive down the overall efficiency of the water heater. At loads higher than those used to determine the EF, the opposite occurs, e.g. the standby component becomes smaller as a percentage and the overall efficiency goes up.

Figure 1 shows the relationship of the LDEF to average daily water heating consumption. The vertical axis is the ratio of the LDEF to the EF. This graph assumes an inlet temperature of 55ºF, a setpoint temperature of 120ºF, and an energy factor (EF) of 0.58.[5] With these assumptions, the LDEF is equal to the EF when daily consumption is about 58 gallons/day. When consumption is greater than 58 gallons/day, the LDEF is greater than the energy factor (the LDEF/EF ratio is greater than one), meaning that the water heater is functioning at efficiency greater than the NAECA test conditions. When consumption is less than 58 gallons/day, the water heater is operating at efficiency less than at NAECA test conditions.

[4] Code Change Proposal for Multifamily Water Heating, Draft April 26, 2002, PG&E and HMG.

[5] An energy factor (EF) of 0.58 is consistent with the new federal appliance efficiency requirements which are scheduled to take effect in 2004.

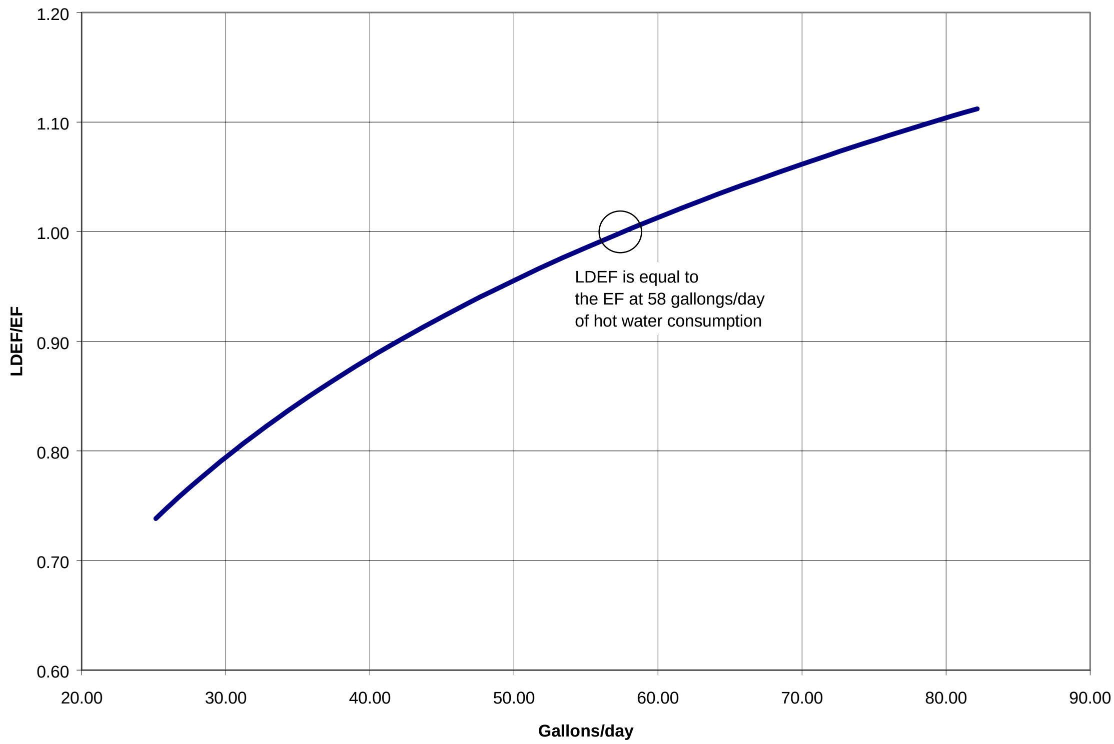

Figure 1 – Relationship Between LDEF and Hot Water Consumption

Existing LDEF Method

The LDEF is given by the following equation in the current methodology.

Equation 1
$$LDEF_j = \ln\left(\frac{ARL_j \times 1000}{365}\right)(a \times EF_j + b) + (c \times EF_j + d)$$

The independent variables are the energy factor (EF) of the water heater and the adjusted recovery load ARL, which is expressed in millions Btu/year. Both LDEF and EF are unitless. The ARL is in millions Btu/year, so the term in brackets following the natural log is in units of thousands Btu/day as converted by the “1000/365” term. The coefficients a, b, c and d depend on the type of water heater and are taken from Table 1.

Table 1 – LDEF Coefficients

Coefficient	Storage Gas	Storage Electric	Heat Pump
a	-0.098311	-0.91263	0.44189
b	0.240182	0.94278	-0.28361
c	1.356491	4.31687	-0.71673
d	-0.872446	-3.42732	1.13480

Water heating energy use (WHEU) is calculated by dividing the adjusted recover load (ARL) by the load dependent energy factor (LDEF), using the following equation. In the current method the ARL includes both loads at the fixture and the "standard" distribution system losses. Under the current standards, the "standard" distribution system is a conventional main and branch distribution system using copper pipe.

Equation 2
$$WHEU_j = \frac{ARL_j}{LDEF_j}$$

For storage electric and gas water heaters, the calculation procedures are simple and rather straightforward. For large storage water heaters (not covered by NAECA federal appliance standards), another calculation procedure is used, based on recovery efficiency and percent standby. The existing procedure for non-NAECA water heaters already works for hourly loads and no change is recommended. Likewise, the current procedure for instantaneous water heaters works for hourly loads and no changes are recommended.

Hourly Modification

The current LDEF method may be easily modified to work for hourly rather than annual loads. The modification is only needed for storage type gas, electric and heat pump water heaters; no changes are needed for large storage water heaters or instantaneous water heaters, since the procedure for these types of equipment already work for hourly calculations. The only term in Equation 1 that must be modified is the portion in brackets after the logarithm. The current equation has the term (ARL*1000/365). The units of ARL are millions Btu/year and the units of the total expression are kBtu/day[6]. If the hourly recovery load (HARL) is expressed in Btu/h, then this value is simply multiplied times 24 and divided by 1000 to get equal units. This relationship is shown in the equation below, where the units of ARL are millions Btu/y and the units of HARL are Btu/h. The resulting units on both sides of the expression are kBtu/day.

Equation 3
$$\frac{ARL \times 1000}{365} = \frac{HARL \times 24}{1000}$$

The modified LDEF equation is as follows, where HARL is the hourly adjusted recovery load in Btu/h.

Equation 4
$$LDEF_j = \ln\left(\frac{HARL_j \times 24}{1000}\right)(a \times EF_j + b) + (c \times EF_j + d)$$

Hourly Adjusted Recovery Load (HARL)

The Existing Method

The adjusted recovery load (ARL) in the current method includes the hot water load at the fixtures plus the distribution losses. The ARL is the total annual load that the water heater "sees." In the current method the ARL is calculated as the standard recovery load (SRL) times the distribution system multiplier (DSM). See Equation 5. The SRL is calculated from Equation 6 and the distribution system multiplier (DSM) is taken from Table 2. The SRL scales with house size up to a maximum of 2,500 ft² and includes loads at the fixture plus losses related to the standard distribution system (see Equation 6). The standard distribution losses are 22%. Values for DSM are given in Table 2. The DSM is unity (1.0) for the standard distribution system, since the equation for SRL includes the distribution losses for the standard distribution system.

Equation 5
$$ARL_K = SRL_k \times DSM_K$$

[6] The "1000" term converts this to kBtu/year, and the "/365" term converts it to kBtu/day.

Equation 6

$$SRL_k = \sum_{i=1}^{n} \frac{0.0855347\left(\frac{CFA_i}{1000}\right)^2 + 3.61307\left(\frac{CFA_i}{1000}\right) + 6.036}{NmbrSys_i}$$

Table 2 – Distribution System Multipliers

Distribution System	DSM - Single Family	DSM-MultiFamily
Standard	1.00	1.00
POU	0.82	na
HWR	0.82	na
Pipe Insulation	0.92	0.92
Parallel Piping	0.86	0.86
Recirc/NoControl	1.52	1.52
Recirc/Timer	1.28	na
Recirc/Temp	1.05	1.05
Recirc/Demand	0.98	na
Recirc/Time+Temp	0.96	na
Recirc/Demand + HWR	0.80	na
Recirc/Demand + Pipe Insulation	0.90	na

Hourly Adjusted Recovery Load (HARL)

As noted above, the recommended method requires an estimate of the hourly adjusted recovery load (HARL). The recommended method for calculating the HARL is consistent with the existing SRL equation, but based on basic engineering principles.

The procedure for calculating the hourly load (HARL) is described in Equation 7 through Equation 11.

Equation 7

$$HARL_K = HSEU_K \times DLM_K$$

This equation gives thermal load for each hour. The hourly load (HARL) is the heat content of the water delivered at the fixture (HSEU) times the distribution loss multiplier (DLM). The DLM will generally be a value greater than one, which means that heat is wasted as water flows from the water heater to the fixture. The DLM is constant for all hours.

Equation 8

$$HSEU_K = \left(GPH_k \times 8.3 \times \Delta T\right)$$

This equation is based on engineering principals and gives the load for each hour at the fixtures (HSEU). The heat content of the water delivered at the fixture is the volume of the draw in gallons (GPH) times the temperature rise (difference between the cold water inlet and the supply temperature) times the heat required to elevate a gallon of water one degree ^{oo}F (the 8.3 constant). Assumptions for GPH and ΔT are recommended in a manner that provides consistency with the existing method (see below).

Equation 9

$$DLM_K = 1 + \left(\left(SDLM_K - 1\right) \times DSM_K\right)$$

This is the equation for the distribution loss multiplier. It combines two terms: the standard distribution loss multiplier (SDLM), which depends on the size of the house and the number of stories, and the distribution system multiplier, which is taken from Figure 2. For point-of-use (POU) distribution systems, where the water heater is located near the draw or fixture, DLM can be assumed to be equal to one, e.g. there are no distribution losses.

Equation 10

$$SDLM_K = 1 + 0.074 + 0.00010 \times CFA$$

This equation gives the standard distribution loss multiplier (SDLM) for one story dwelling units. Results from this equation are plotted in Figure 2. See also Equation 11 for two and three-story dwelling units.

Equation 11

$$SDLM_K = 1 - 0.007 + 0.00008 \times CFA$$

This equation gives the standard distribution loss multiplier (SDLM) for two and three story dwelling units. Results from this equation are plotted in Figure 2.

The development of Equation 7, Equation 9, Equation 10, and Equation 11 is documented win the research report developed by Davis Energy Group.

where

$HARL_K$ Hourly adjusted recovery load (Btu).

$HSEU_K$ Hourly standard energy use (Btu). This is the amount of heat contained in the water that is delivered at the hot water fixtures.

DLM_K Distribution loss multiplier (unitless).

GPH_K Hourly hot water consumption (gallons). Assumptions on hourly hot water use are provided later which are consistent with the current method.

8.3 The heat in Btu that must be added to one gallon of water to elevate the temperature by one degree ºF.

ΔT Temperature difference between cold water inlet and supply temperature (ºF). Assumptions are recommended later in this research report that provide consistency with the current procedure.

$SDLM_K$ Standard distribution loss multiplier (unitless). This is calculated using Equation 10 for single story buildings and from Equation 11 for residences with two or more stories.

DSM_K Distribution system multiplier (unitless). These values are taken from Table 3.

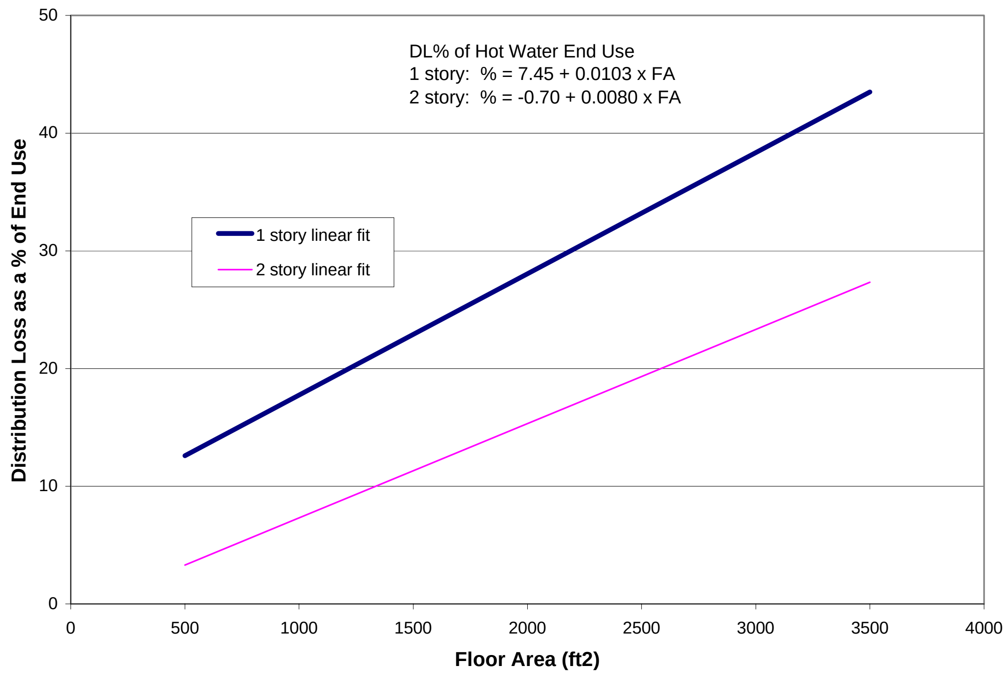

Figure 2 – Relationship of SDLM to Floor Area

Table 3 – Proposed ACM DSMs

Distribution System Measure	Code	Systems Serving Individual Units: Mandatory Kitchen Pipe Insulation	Systems Serving Individual Units: Basecase is Standard Main and Branch	Systems Serving Multiple Units
Pipe Insulation (all lines)	PIA	0.92	0.73	n. a.
Pipe Insulation (kitchen lines)	PIK	1.00	0.79	n. a.
Point of Use	POU	0.00	0.00	0.00
Parallel Piping	PP	1.09	0.88	1.09 or 0.88
Recirculation (no control)	RNC	4.81	3.80	To be Provided
Recirculation + timer control	RTm	3.22	2.54	To be Provided
Recirculation + temperature control	RTmp	3.97	3.14	To be Provided
Recirculation + timer/temperature	RTmTmp	2.65	2.09	To be Provided
Recirculation + demand control	RDmd	1.39	1.10	To be Provided

Table 3 shows the recommended distribution loss multipliers. These values are used in Equation 9 to determine the overall distribution loss multiplier (DLM). For systems serving individual dwelling units, there are two columns. The one labeled "Mandatory Kitchen Pipe Insulation" assumes that pipe insulation to the kitchen is a mandatory requirement and therefore part of the basecase. The one labeled "Basecase is Standard Main and Branch" assumes that mandatory pipe insulation to the kitchen fixtures is not mandatory. In the first case, there is no credit for insulating the kitchen lines since they are required and mandatory. In the second case a credit is offered.

Average Daily Hot Water Consumption

When Equation 6 for SRL was developed, the following assumptions were made.

- The temperature difference between the inlet and the outlet was assumed to be 65 ºF. There are no differences between climates, e.g. the SRL is the same in a cold climate like 1 or 16 and warm climates like 7.

- Distribution losses for the "standard" system are 22%. This is equivalent to multiplying the SRL by 0.82 to remove the distribution losses to get the load from the fixture draws.

- Hot water consumption varies with the conditioned floor area of each dwelling unit, but does not vary by dwelling unit type, e.g. multifamily vs. single family.

Based on these assumptions, Equation 6 can be solved for the gallons per day of average hot water consumption. The hot water use is a constant 24 gallons/day plus an additional 16 gallons per day for each 1,000 ft² of conditioned floor area. Consumption is about 35 gallons/day for a small 700 ft² apartment, about 65 gallons/day for a 2,500 ft² dwelling unit. SRL is capped at 2,500 ft² so all dwelling units above this size are assume to have an average daily consumption of 65 gallons/day. The equation for hot water consumptions can be expressed as follows:

Equation 12 $$GPD = 24 + 0.016 \times CFA$$

where

GPD Average daily hot water consumption (gallons/day).

CFA Conditioned floor area (ft²). CFA is capped at 2,500 ft² in the current method. This constraint will be retained for consistency.

Figure 3 shows the relationship between floor area and water consumption that is built into the existing water heating methodology.

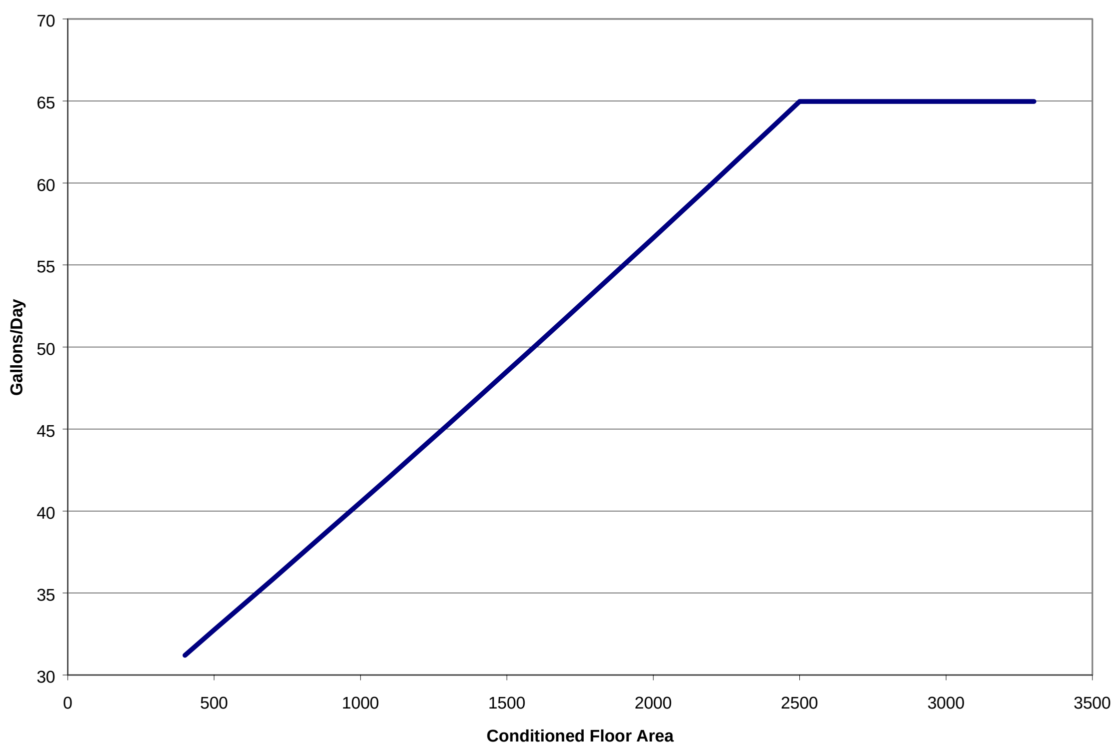

Figure 3 – Standard Hot Water Consumption (gallons/day)
This figure shows the standard hot water consumption in gallons/day. This is calculated from the current SRL equation assuming a delta T of 65 ºF, and 22% distribution losses (0.82 adjustment factor).

Inlet Temperature

The SRL equation used in the current standards is based on a constant lift of 65 ºF, which can be considered a constant supply temperature of 120 ºF and a constant inlet temperature of 55 ºF. Other combinations of supply temperature and inlet temperature are possible as long as the temperature difference is 65 ºF. To be consistent with the existing water heating methodology, a delta-T of 65 ºF would be specified as a fixed input to the procedure. An alternative would be to assume that the inlet temperature varies by climate and by month and is equal to the assumed ground temperature used for modified slab loss model. Table 4 shows the temperatures used for the slab loss model. Using these values would provide more accuracy and would result in greater loads in the winter.

Table 4 – Monthly Ground Temperature Data (ºF)

Climate Zone	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1	52.2	51.5	51.4	51.8	53.1	54.5	55.6	56.4	56.4	55.8	54.7	53.4
2	53.3	51.5	51.4	52.2	55.6	58.9	61.8	63.6	63.8	62.3	59.5	56.3
3	55.1	54.1	54.0	54.5	56.5	58.5	60.3	61.4	61.5	60.6	58.9	56.9
4	55.5	54.0	53.9	54.6	57.5	60.3	62.8	64.3	64.5	63.2	60.8	58.0
5	55.7	54.8	54.7	55.2	56.9	58.7	60.2	61.1	61.2	60.4	59.0	57.3
6	59.1	58.1	58.0	58.5	60.4	62.4	64.0	65.1	65.2	64.3	62.7	60.8
7	60.1	59.1	59.0	59.5	61.5	63.4	65.2	66.2	66.3	65.5	63.8	61.9
8	60.0	58.8	58.7	59.2	61.6	63.9	66.0	67.3	67.4	66.3	64.3	62.1
9	60.5	59.1	59.0	59.7	62.2	64.8	67.1	68.5	68.6	67.5	65.3	62.8
10	59.4	57.6	57.4	58.3	61.8	65.2	68.2	70.1	70.2	68.7	65.8	62.4
11	54.9	52.4	52.2	53.4	58.2	63.0	67.2	69.8	70.0	67.9	63.8	59.2
12	54.6	52.5	52.3	53.3	57.3	61.3	64.8	67.0	67.2	65.4	62.0	58.1
13	57.5	54.7	54.5	55.8	61.0	66.2	70.6	73.5	73.7	71.4	67.0	62.0
14	54.2	51.2	51.0	52.4	58.2	63.9	68.8	72.0	72.2	69.7	64.8	59.3
15	66.8	64.0	63.8	65.1	70.4	75.8	80.4	83.3	83.6	81.2	76.7	71.5
16	44.4	41.8	41.6	42.8	47.7	52.6	56.8	59.5	59.7	57.5	53.4	48.7

Hourly Schedules

Equation 12 gives the average daily hot water consumption. It is necessary to convert this to hourly consumption using a schedule. The approach for developing hourly schedules is to collect data from as many sources as are available, to analyze these data and to recommend an hourly schedule for use with the standards. The following sources of data were considered.

1. James D. Lutz, et. al. Modeling patterns of hot water use in households, LBNL-37805 Rev. November 1996.

2. PG&E Regulatory Cost of Service Department, Appliance Metering Project, Figure 3-20 Average Water heater Load Shapes by Type of Day and Season.

3. Goldner, Fred, and Norine H. Karins. *DHW Modeling: System Sizing and Selection Criteria – A Study of Baseloads and Seasonal Efficiency: Final Report 99-2*. New York State Energy Research and Development Authority. 1999.

4. Perlman, M., and N.H. Milligan. *Hot Water and Energy Use in Apartment Buildings.* ASHRAE Transactions. 1988.

Based on these data, an hourly schedule is recommended based on the PG&E data. This data is specific to California and when compared to the other data, it seems the most reasonable. There are significant variations between weekdays and weekends and it is recommended that these be respected in the schedules. These data are shown in Table 5 and plotted in Figure 4. The data indicate that the patterns of water heating consumption vary between weekdays and weekends and also between summer and winter. There is a larger and earlier spike on weekdays. The spike is later and flatter on the weekends.

Table 5 – Recommended Water Heating Schedules

Hour	Weekday	Weekend
1	0.014	0.018
2	0.008	0.010
3	0.009	0.009
4	0.011	0.008
5	0.020	0.015
6	0.044	0.023
7	0.089	0.026
8	0.107	0.047
9	0.089	0.077
10	0.066	0.083
11	0.052	0.074
12	0.038	0.061
13	0.036	0.051
14	0.033	0.043
15	0.032	0.039
16	0.026	0.039
17	0.042	0.052
18	0.048	0.058
19	0.052	0.056
20	0.047	0.052
21	0.042	0.047
22	0.039	0.044
23	0.036	0.040
24	0.022	0.028
Sum	1.000	1.000

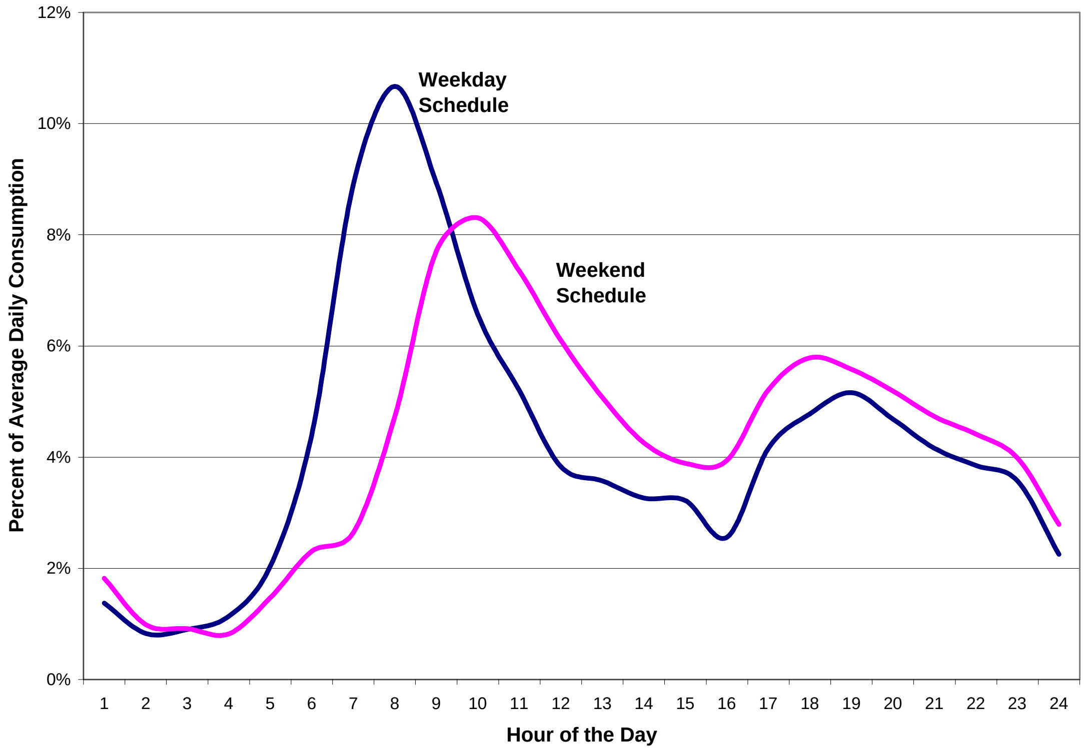

Figure 4 – Hourly HW Schedule – Day Type and Season – PG&E

This figure shows that hot water consumption peaks more for weekdays as persons arise at more or less the same time. On weekends, the morning peak occurs later in the day and is flatter.

Define the Standard Water Heating Systems

- For systems serving individual dwelling units, the standard design system would be the same as defined in the 2001 standards and ACM. The standard system is a gas storage water heater in minimum compliance with the NAECA requirements. For a 50 gallon water heater, EF requirement is currently 0.525, but this will change to 0.575 when the new NAECA requirements take effect in 2004. The size and EF of the standard design varies with the size of the water heater proposed for the proposed building. The standard system has a standard distribution system as defined above and in the Davis Energy Group research.

- For systems serving multiple dwelling units, a central recirculating water heating system shall be installed with a single water heater that meets the minimum efficiency requirements of Section 113 and distribution system controls capable of automatically turning off the circulating pump when hot water is not required. Distribution system piping shall be insulated in accordance with Section 123, Table 1-G for re-circulating sections of service water heating systems.

Example Calculations

An example is provided of hourly water heating calculations using the recommended procedure.. The example assumes a gas storage water heater with an EF of 0.58. The dwelling unit has an area of 2,100 ft^2. The ARL is 14.0 million Btu/y. For a single day, the ARL is 38,358 Btu. Table 6 shows the hourly loads, the calculated LDEF for each hour and the water heating energy use (WHEU). As expected, the LDEF is very low at night when there is no load and higher in the morning when hourly loads are high. The results of the hourly calculation are 64,608 Btu, which is very close to 65,870 Btu, the calculated value for the whole day, not using the hourly method.

Table 6 – Example of Hourly Water Heater Calculations

Hour	Hourly Schedule	Hourly Adjusted Recovery Load (Btu)	Load Dependent Energy Factor (LDEF)	Water Heater Energy Use (WHEU)
1	0.013	501	0.37	1355
2	0.009	358	0.31	1161
3	0.009	358	0.31	1161
4	0.011	429	0.34	1257
5	0.021	787	0.45	1739
6	0.045	1718	0.60	2884
7	0.093	3578	0.73	4902
8	0.103	3936	0.75	5266
9	0.090	3435	0.72	4755
10	0.071	2719	0.68	4001
11	0.052	2004	0.62	3213
12	0.039	1503	0.57	2632
13	0.035	1360	0.55	2460
14	0.034	1288	0.54	2373
15	0.030	1145	0.52	2197
16	0.022	859	0.47	1833
17	0.043	1646	0.59	2801
18	0.047	1789	0.60	2967
19	0.049	1861	0.61	3050
20	0.045	1718	0.60	2884
21	0.043	1646	0.59	2801
22	0.041	1574	0.58	2717
23	0.035	1360	0.55	2460
24	0.021	787	0.45	1739
Total	1.000	38358	n.a.	64608

Recommendations

Proposed Standards Language

SECTION 151 – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES

(a) **Basic Requirements**. New low-rise residential buildings shall meet all of the following:

1. The requirements of Sections 111 through 118 applicable to new residential buildings.
2. The requirements of Section 150 (mandatory features).
3. Either the performance standards (energy budgets) or the prescriptive standards (alternative component packages) set forth in this section for the climate zone in which the building will be located. Climate zones are shown in Figure 1-A.

   ALTERNATIVE to Section 151 (a) 3: If a single contiguous subdivision or tract falls in more than one climate zone, all buildings in the subdivision or tract may be designed to meet the performance or prescriptive standards for the climate zone which contains 50 percent or more of the dwelling units.

   NOTE to Section 151 (a) 3: The California Energy Commission shall periodically update, publish, and make available to interested persons and local building departments a document entitled *California Climate Zone*

Descriptions for New Buildings, (July 1995), which shall contain a precise description of the metes and bounds for climate zone boundaries depicted in Figure 1-A and a list of the communities in each zone.

4. For other provisions applicable to new low-rise residential buildings, refer to Section 100 (c).

(b) **Performance Standards**. A building complies with the performance standard if its combined calculated *TDV energy* use for water heating [Section 151 (b) 1] and space conditioning [Section 151 (b) 2] is less than or equal to the combined maximum allowable *TDV energy* use for both water heating and space conditioning, even if the building fails to meet either the water heating or space conditioning budget alone.

1. **Water-heating budgets.** The ~~budgets for~~ water-heating ~~systems are~~ budget for each climate zone shall be the calculated *TDV energy* required for water heating in buildings in which the basic requirements of Section 151 (a) and the measures in Alternative Component Package D are installed. To determine the space-conditioning budget, use an approved calculation method. ~~those calculated from Equation (1-N).~~

~~**EQUATION (1-N)—ANNUAL WATER HEATING BUDGET (AWB) EQUATION**~~

~~For dwelling units less than 2500 ft.²:~~

$$AWB\left(kBtu/yr.\text{-}ft.^2\right) = \frac{(16370)}{CFA} + 4.85$$

~~For dwelling units equal to or greater than 2500 ft.²:~~

$$AWB\left(kBtu/yr.\text{-}ft.^2\right) = \frac{(26125)}{CFA}$$

~~**WHERE**~~

~~*CFA* = The building's conditioned floor area in square feet.~~

~~The annual water-heating budget calculated from Equation (1-N) may be met by either:~~

~~A. Calculating the energy consumption of the proposed water-heating system using an approved calculation method without an external insulation wrap; or~~

~~B. Installing any gas storage-type nonrecirculating water-heating system that does not exceed 50 gallons of capacity, and that meets the minimum standards specified in the Appliance Efficiency Standards.~~

~~**NOTE:** Storage gas water heaters with an energy factor of less than 0.58 must be externally wrapped with insulation having an installed thermal resistance of R-12 or greater in accordance with Section 150 (j).~~

2. **Space-conditioning budgets**. The space-conditioning budgets for each climate zone shall be the calculated consumption of energy from depletable sources required for space conditioning in buildings in which the basic requirements of Section 151 (a) and the measures in Alternative Component Package D are installed. To determine the space-conditioning budget, use an approved calculation method.

(c) **Compliance Demonstration Requirements for Performance Standards**. The application for a building permit shall include documentation which demonstrates, using an approved calculation method, that the new building has been designed so that its TDV energy use ~~from depletable energy sources~~ does not exceed the combined water-heating and space-conditioning energy budgets for the appropriate climate zone.

1. To demonstrate compliance, the applicant's documentation shall:

A. Determine the combined TDV energy budget for the proposed building by adding the following:

i. The annual water-heating budget ~~calculated from Equation (1-N)~~ (kBtu/yr.-ft.²) as determined pursuant to Section 151 (b) 1 and

ii. The annual space-conditioning budget (kBtu/yr.-ft.²) as determined pursuant to Section 151 (b) 2.

B. Calculate the ~~source~~ TDV energy consumption total of the proposed building, using the proposed building's actual glazing area, orientation, and distribution, and its actual energy conservation and other features, including the actual water-heating, space-conditioning equipment and duct conditions and locations.

Include in the calculation the energy required for building cooling even if the building plans do not indicate that air conditioning will be installed.

2. The proposed building design complies if the energy consumption calculated pursuant to Section 151 (c) 1 B is equal to or less than the combined energy budget established in Section 151 (c) 1 A.

MULTIPLE ORIENTATION ALTERNATIVE to Section 151 (c): A permit applicant may demonstrate compliance with the energy budget requirements of Section 151 (a) and (b) for any orientation of the same building model if the documentation demonstrates that the building model with its proposed designs and features would comply in each of the four cardinal orientations.

(d) **Compliance Methods for Performance Standards**. Compliance with the energy budget requirements of Section 151 (a) 3 and 151 (b) must be demonstrated by using the compliance version of the commission's Public Domain Computer Program or any alternative calculation method approved by the commission for use in complying with Section 151 (a) and 151 (b).

~~**NOTE:** Compliance with the water-heating budget need not be demonstrated using any of the calculation methods referred to in Section 151 (d), if all the requirements of Section 151 (b) 1 B are met.~~

(e) **Required Calculation Assumptions.** The commission shall publish the assumptions and calculation methods it used to develop the standards for low-rise residential buildings, including those specified in Section 151. In determining the water-heating and space-conditioning budgets and calculating the energy use of the proposed building design, the applicant shall use only these assumptions and calculation methods (or alternative assumptions and methods approved by the commission or its executive director).

1. Such assumptions shall include, but not be limited to, the following:

A. The operating conditions regarding indoor temperature; occupancy loads and schedules; equipment loads and operation schedules, including lighting, HVAC, and miscellaneous electrical; and outdoor weather conditions;

B. The physical characteristics of building pressurization, interior heat transfer, film coefficients, solar heat gain coefficient and operation of installed shading devices, ground temperatures, and the method of determining slab heat loss;

C. The applicable modeling procedures for the assumptions, design conditions, and physical characteristics described in Section 151 (e) 1.

D. Water heating use schedules, cold water inlet temperatures, and average outdoor temperatures for calculating water heating loads.

EXCEPTION to Section 151 (e) 1: The commission may approve alternative schedules, assumptions, and performance modeling procedures that may be used in lieu of those described in Section 151 (e) 1, provided such alternatives do not alter the efficiency level required by these standards.

2. The total calculated annual energy consumption shall include all energy used for comfort heating, comfort cooling, ventilation for the health and comfort of occupants, and service water heating.

3. Heat transfers within the same building to adjacent spaces that are not covered by the permit and that are independently provided with space conditioning may be considered to be zero. Heat transfers to spaces not yet provided with space conditioning may be modeled as separate unconditioned zones, or as outdoor conditions.

4. The total calculated annual energy consumption need not include energy from any nondepletable sources, regardless of the purpose of the energy consumed.

5. The U-factor of installed manufactured fenestration products shall be those certified by an approved independent certification organization in accordance with Section 116. The U-factor of field-fabricated fenestration products shall be those values from Section 116, Table 1-D, based on an approved method that determines the area weighted average U-factor for generic types of products.

6. Solar heat gain coefficients for interior shading devices used with fenestration products shall be 0.68 for vertical fenestration products and 1.0 for non-vertical fenestration products. No other solar heat gain coefficients shall be used for interior shading. The calculations for vertical fenestration products include the effects of draperies and insect screens without installation being verified at the time of final inspection.

(f) **Prescriptive Standards/Alternative Component Packages**. Buildings that comply with the prescriptive standards shall be designed, constructed, and equipped to meet all of the requirements of one of the alternative packages of components shown in Tables 1-Z1 through 1-Z16 for the appropriate climate zone shown in Figure 1-A. Installed components shall meet the following requirements:

NO CHANGES TO 1 THROUGH 7.

8. **Water-heating systems.** Water heating systems shall meet the requirements of either A or B.

All water-heating systems must meet the water-heating budgets calculated from Equation (1-N).

A. **NOTE to Section 151 (f) 8:** Any For systems serving individual dwelling units, a single gas storage type water heater shall be installed that has a tank capacity type domestic water heater of 50 gallons or less, and no recirculation pumps, which is certified as meeting the Appliance Efficiency Standards, and which meets tank insulation requirements of Section 150 (j) may be assumed to meet the water heating budget.

B. For systems serving multiple dwelling units, a central recirculating water heating system shall be installed with a single water heater that meets the minimum efficiency requirements of Section 113 and distribution system controls capable of automatically turning off the circulating pump when hot water is not required. Distribution system piping shall be insulated in accordance with Section 123, Table 1-G for re-circulating sections of service water heating systems.